IBD Sanity Checks: Part I

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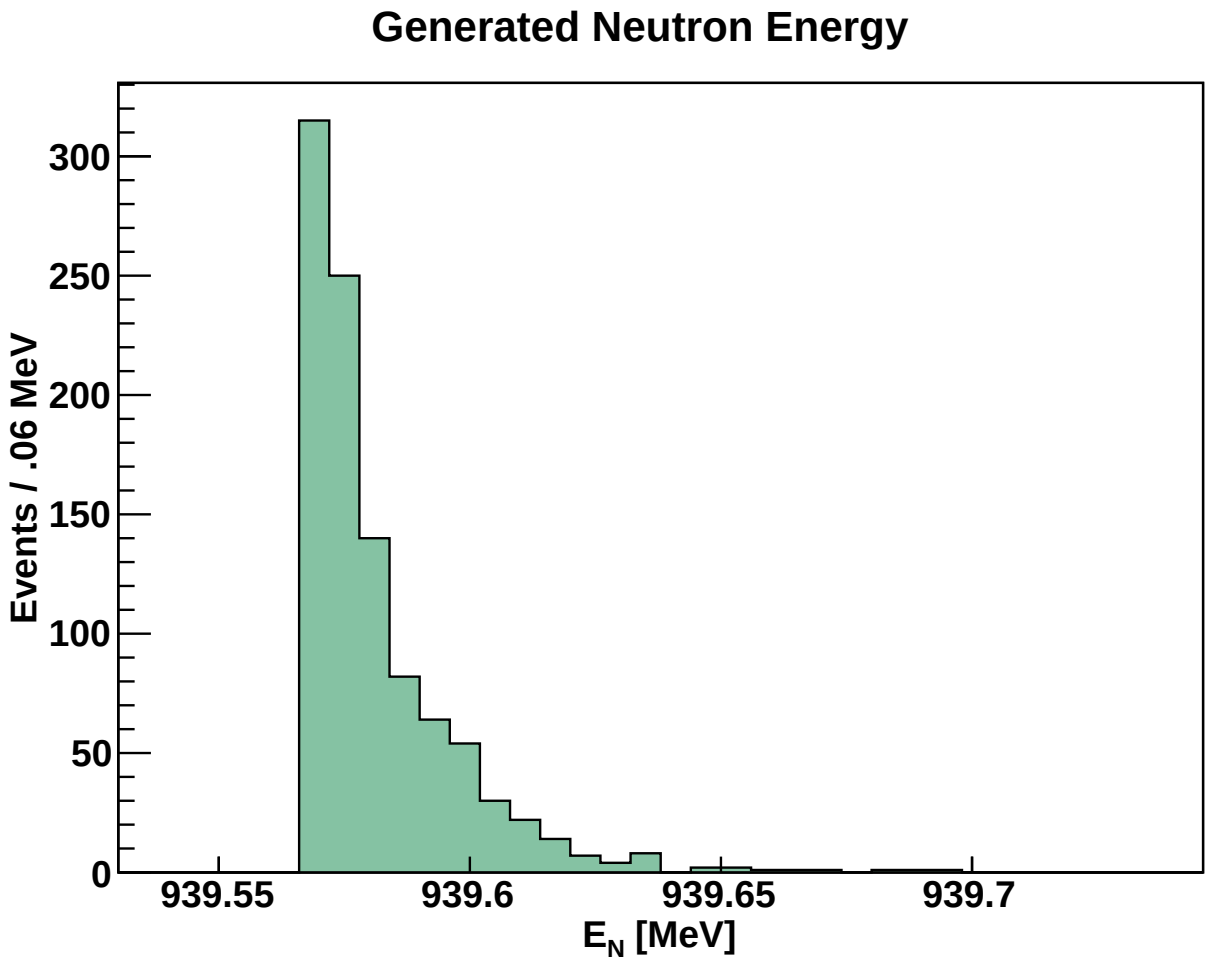
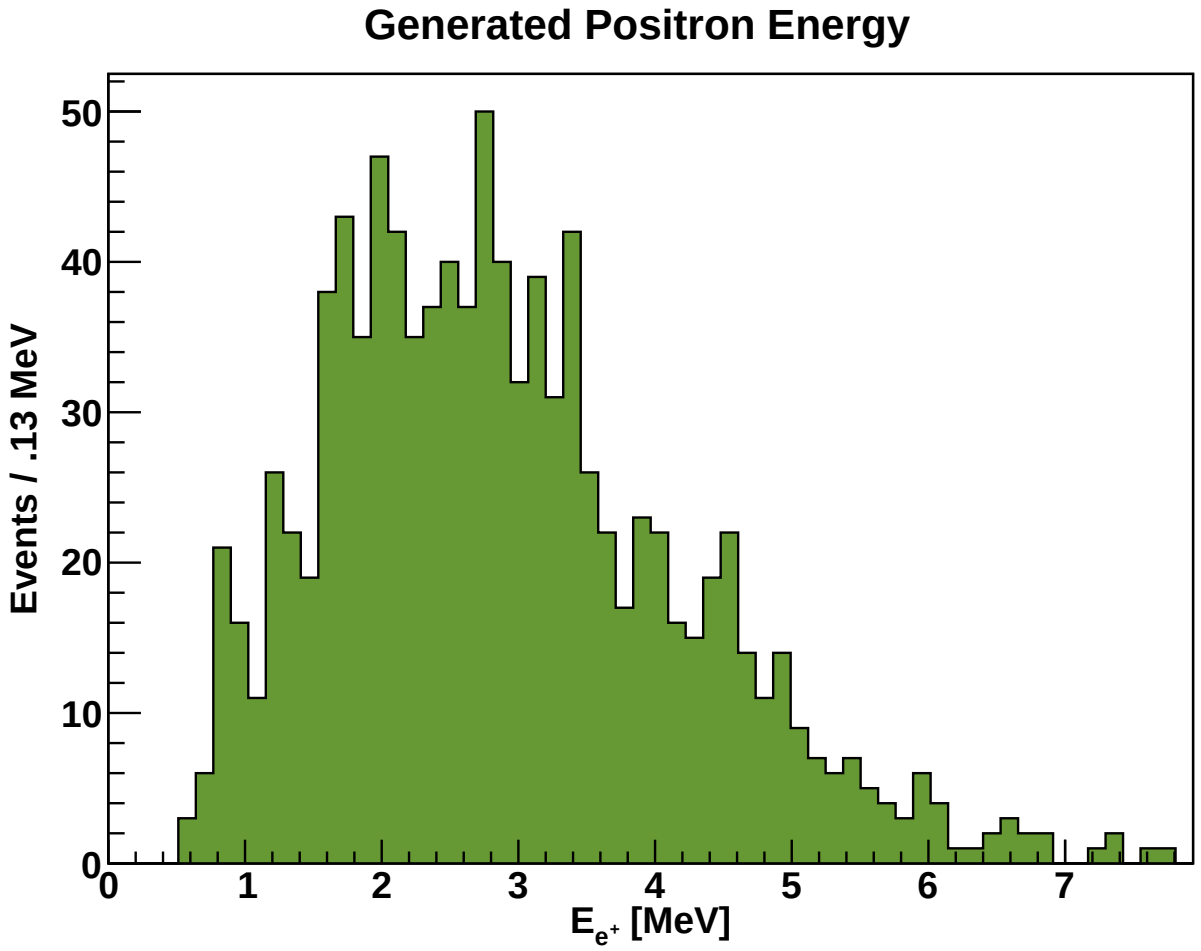
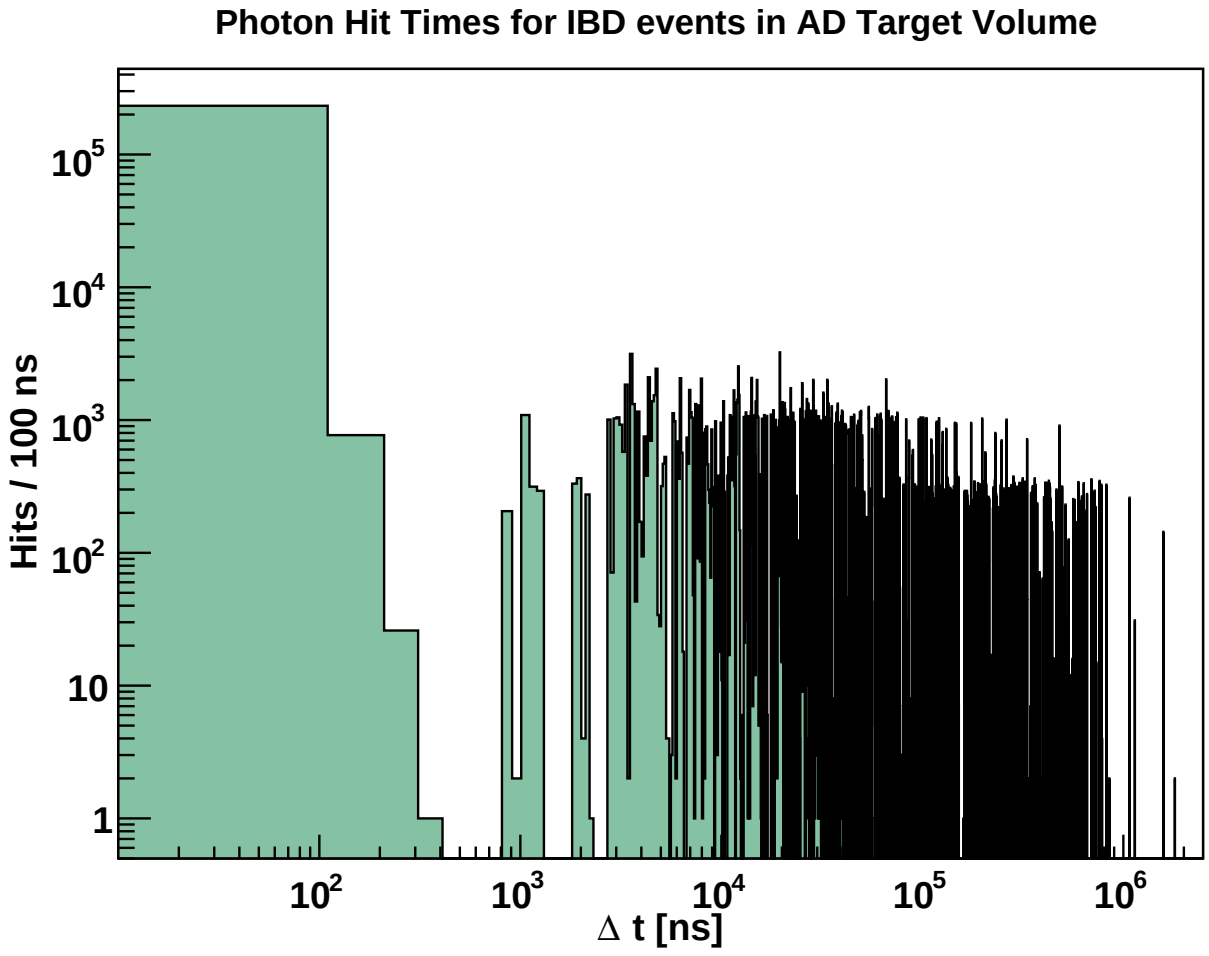
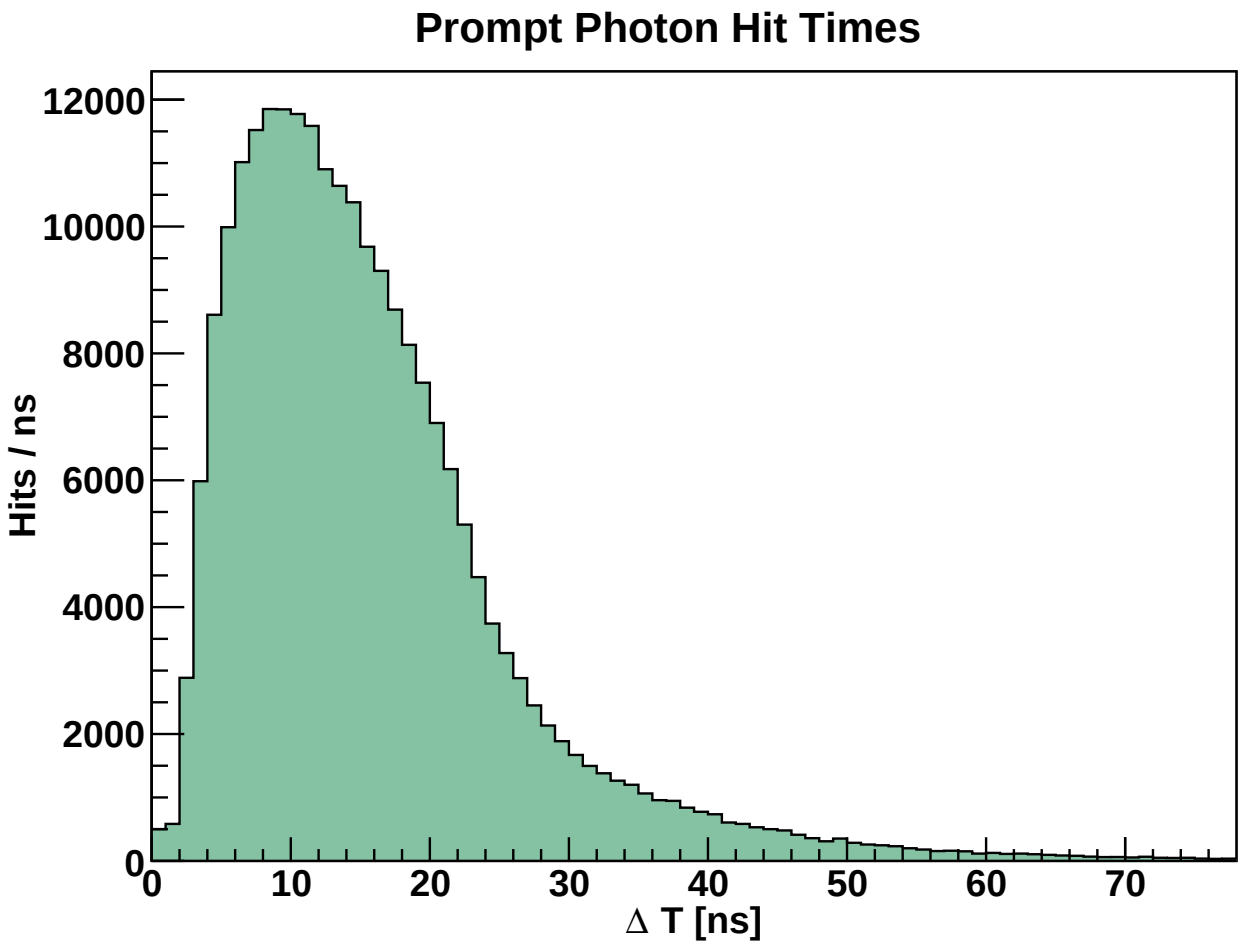
topics

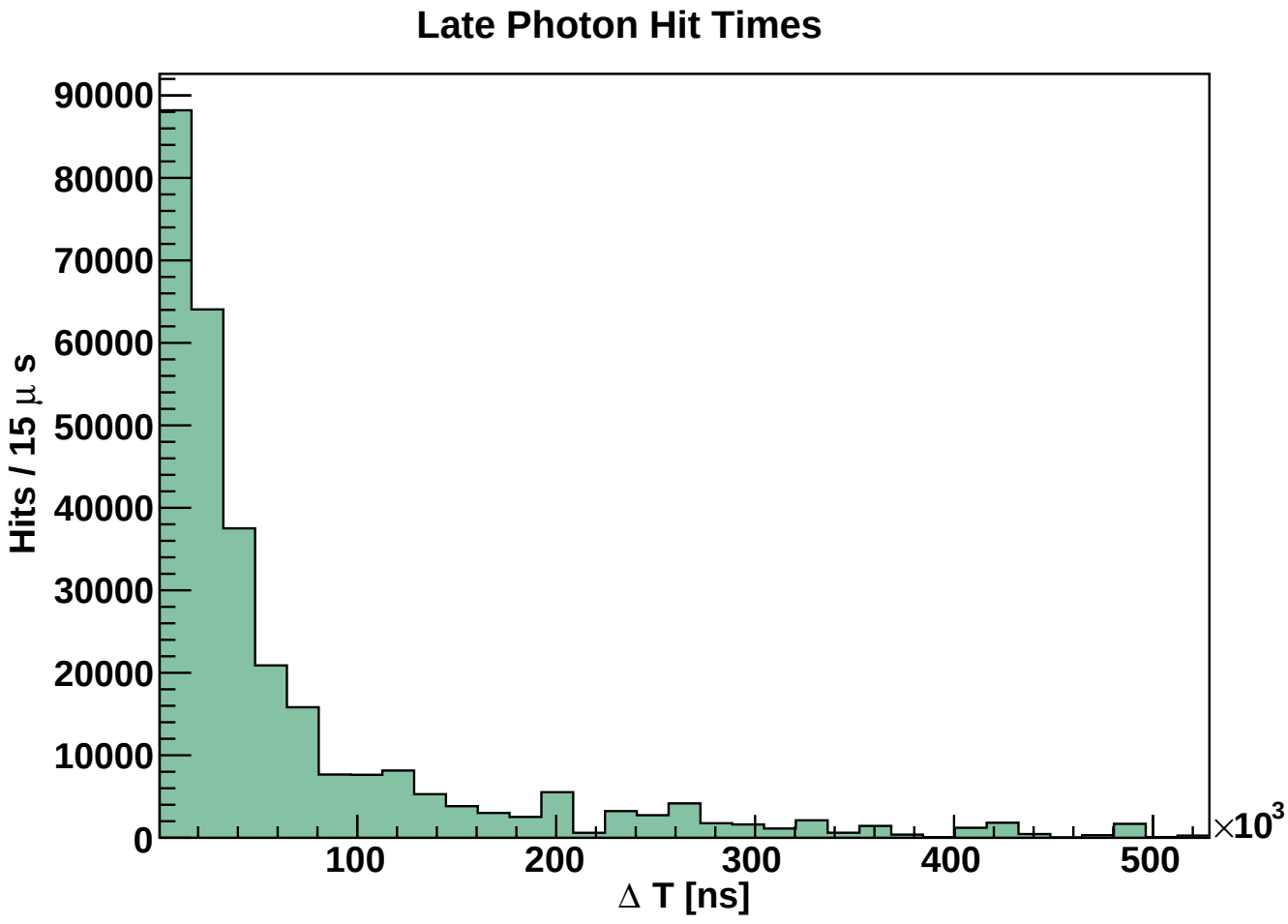
1. IBD Generation
2. Photon Hit Times
3. Neutron Moderation

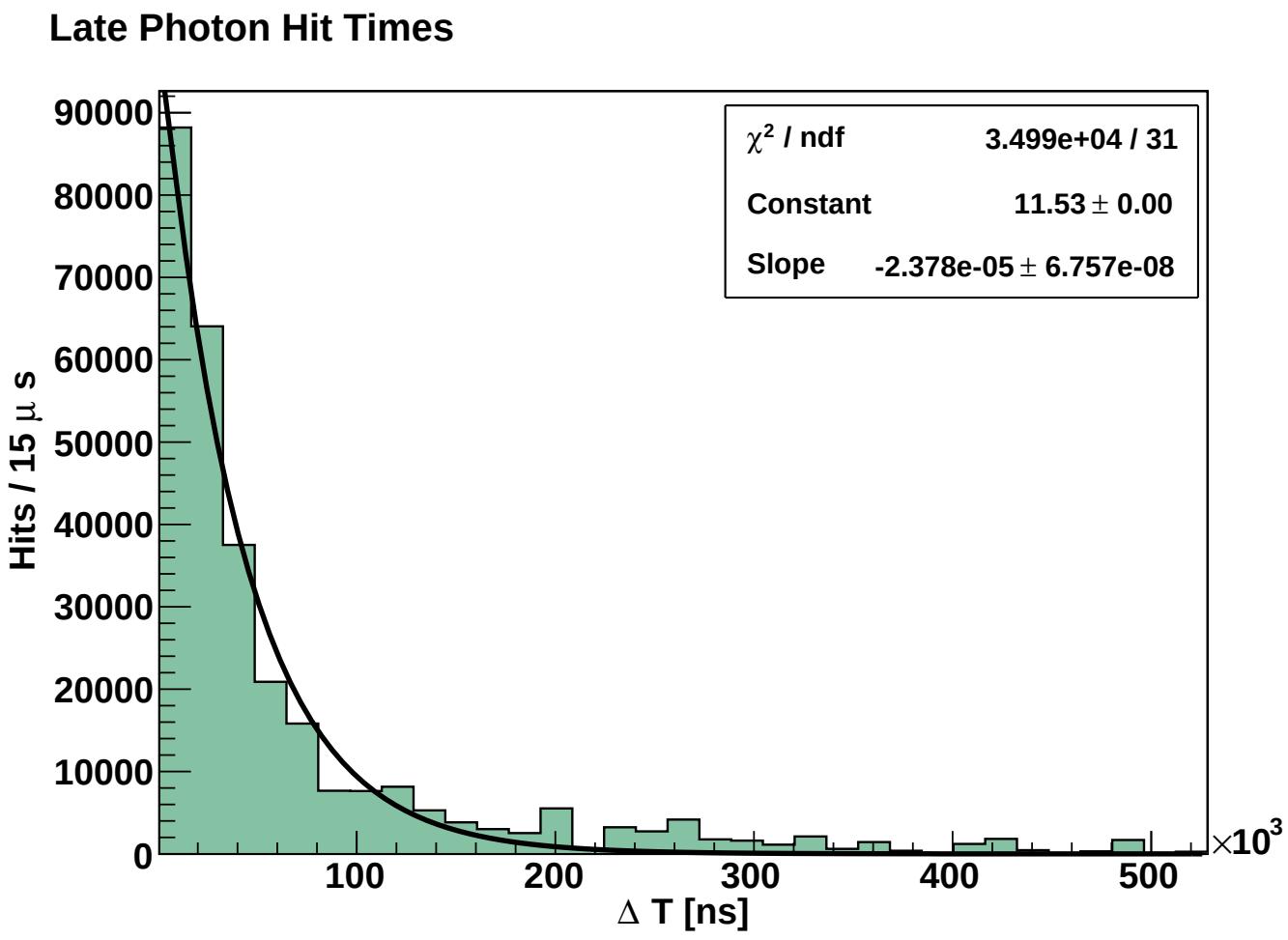

Generated Neutron Energy
Events / .06 MeV
300
250
200
150
100
50
0
939.55
939.6
939.65
939.7
E_N [MeV]


Generated Positron Energy
Events / .13 MeV
0
10
20
30
40
50
0
1
2
3
4
5
6
7
E_{e^+} [MeV]


Photon Hit Times for IBD events in AD Target Volume
Hits / 100 ns
10^5
10^4
10^3
10^2
10
1
10^2
10^3
10^4
10^5
10^6
Δ t [ns]


Prompt Photon Hit Times
Hits / ns
12000
10000
8000
6000
4000
2000
0
0
10
20
30
40
50
60
70
Δ T [ns]


Late Photon Hit Times
Hits / 15 μ s
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
100
200
300
400
500
×10^3
Δ T [ns]


Late Photon Hit Times
χ^2 / ndf 3.499e+04 / 31
Constant 11.53 ± 0.00
Slope -2.378e-05 ± 6.757e-08
Hits / 15 μ s
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
100
200
300
400
500
×10³
Δ T [ns]

What interactions should govern neutron transport in scintillator?

- No coulomb interaction $\longrightarrow$ neutrons are penetrating
- IBD neutrons are epithermal $\longrightarrow$ elastic scattering should dominate
- radiative neutron capture should go as $\frac{1}{v}$ at thermal energies
- fission should be negligible for thermalized neutrons for lack of fissile material

Elastic scattering of neutrons on light nuclei are understood [1]
The Energies of neutrons after scattering are uniform in the range:

$$\frac{\mathrm{A}-1}{\mathrm{A}+1}^2 \mathrm{E}_0 < \mathrm{E} < \mathrm{E}_0 \tag{1}$$

At low energies scattering is isotropic, some math gives:

$$ln\frac{\mathrm{E}_0}{\mathrm{E}(\theta)} = ln\frac{(\mathrm{A}+1)^2}{\mathrm{A}^2+1+2\mathrm{A}\cos(\theta)} \tag{2}$$

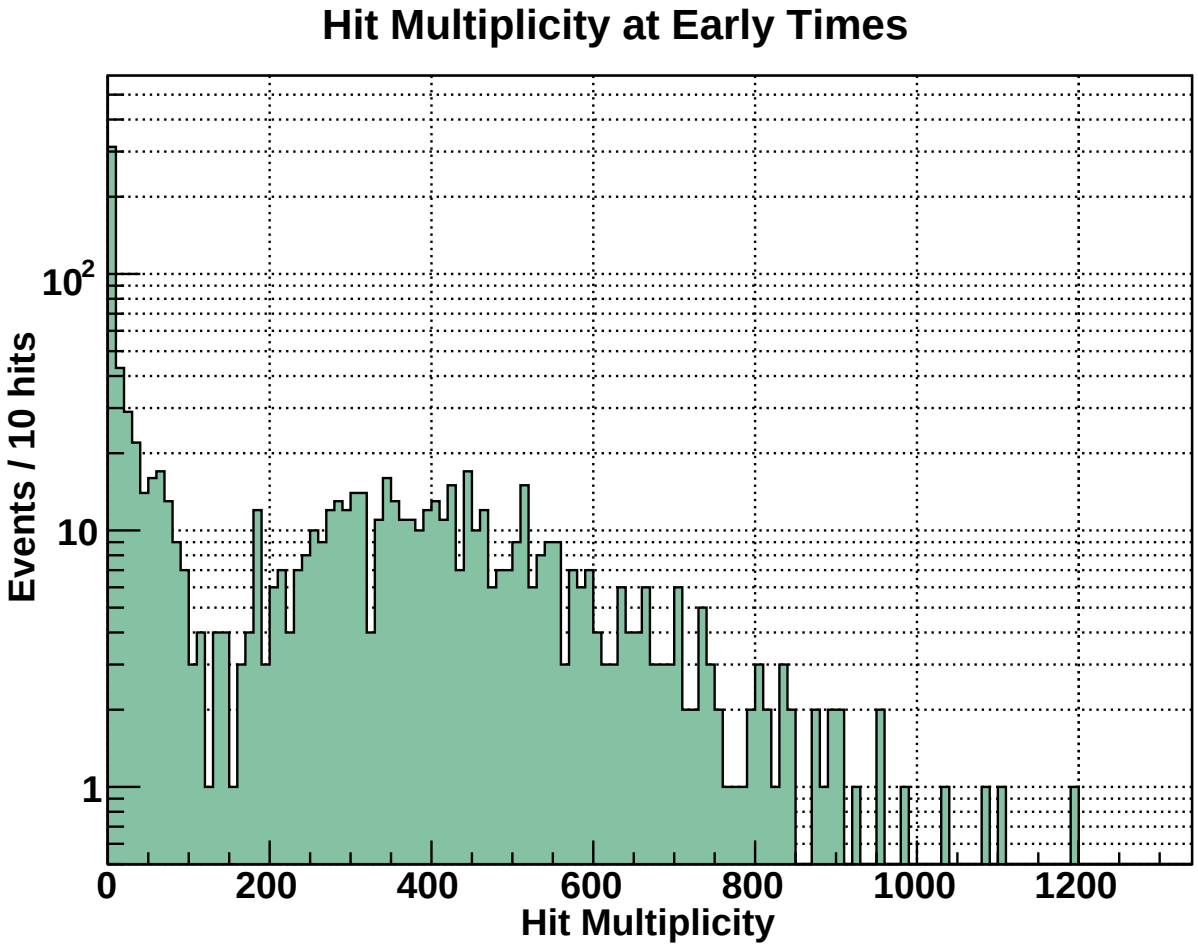
Averaged over all scattering angles this quantity is known as the "averaged lethargy" ξ
For Hydrogen: $\xi = 1$, Carbon-12:$\xi = 0.158$

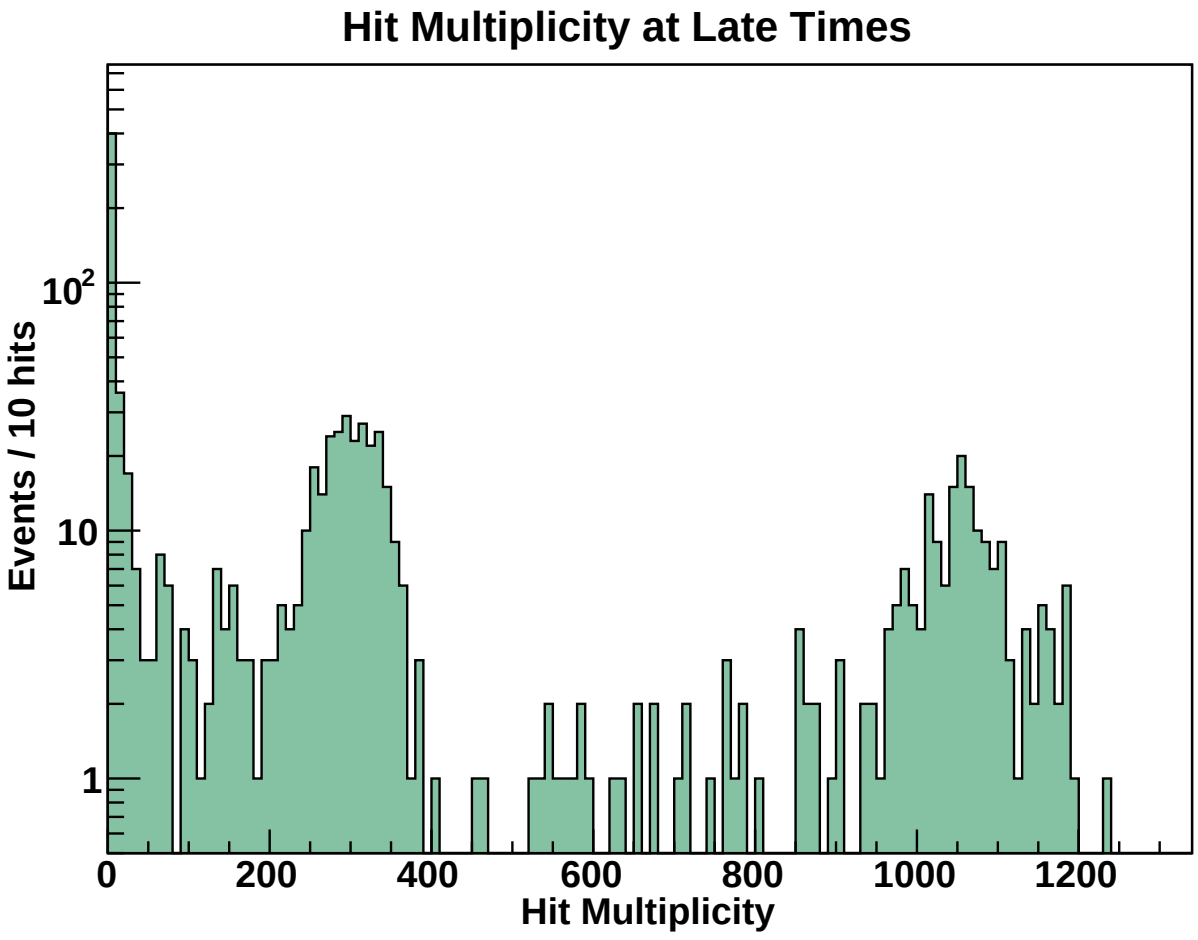
[1] See E.U. Condon, G. Breit: Phys. Rev. 49, 229 (1936)

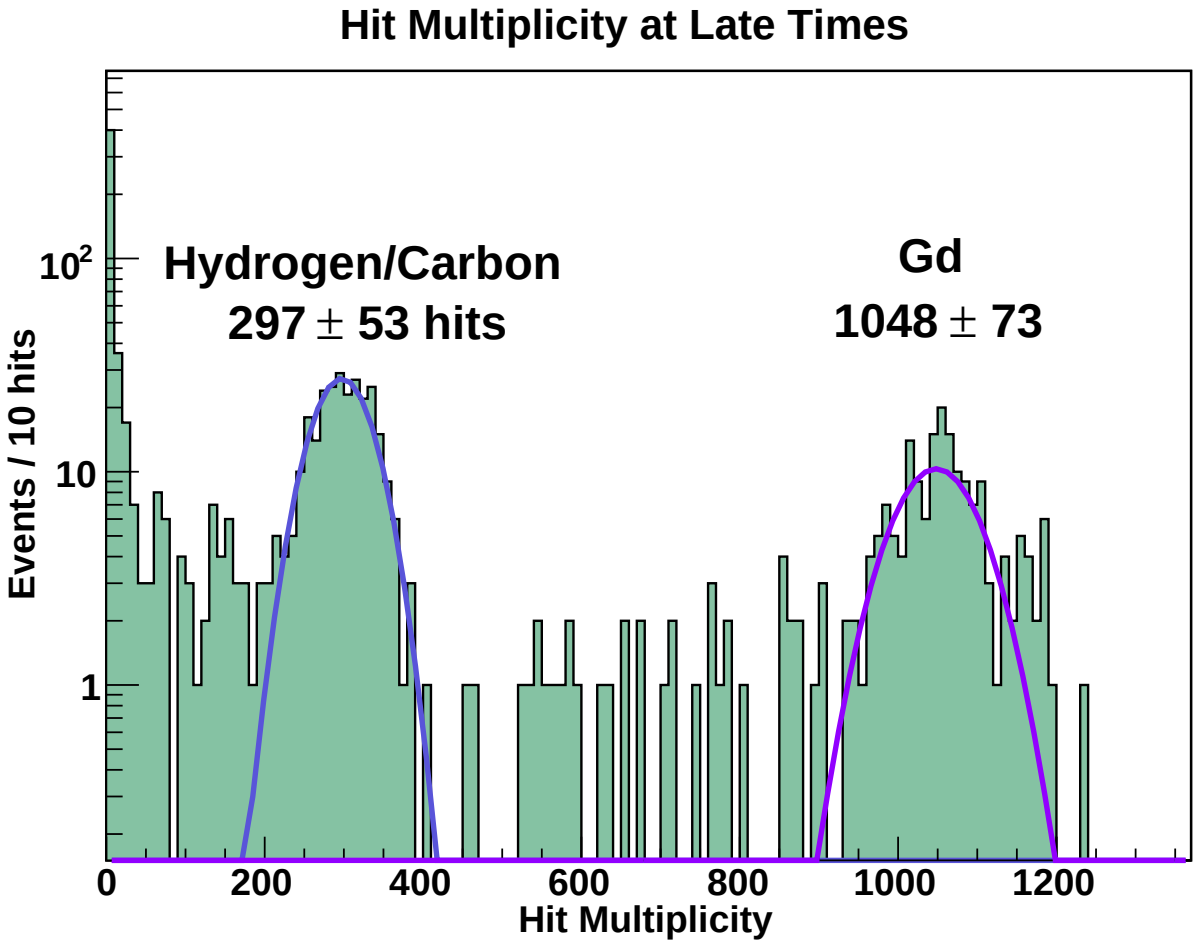
So... In any plot that reflects energy deposition, we should expect to see:

- lots of light at early times from positiron annihilation
- 3 peaks at late times from the neutron
  - few keV from moderation
  - 2 MeV from H / C-12 capture
  - 8 MeV from Gd capture

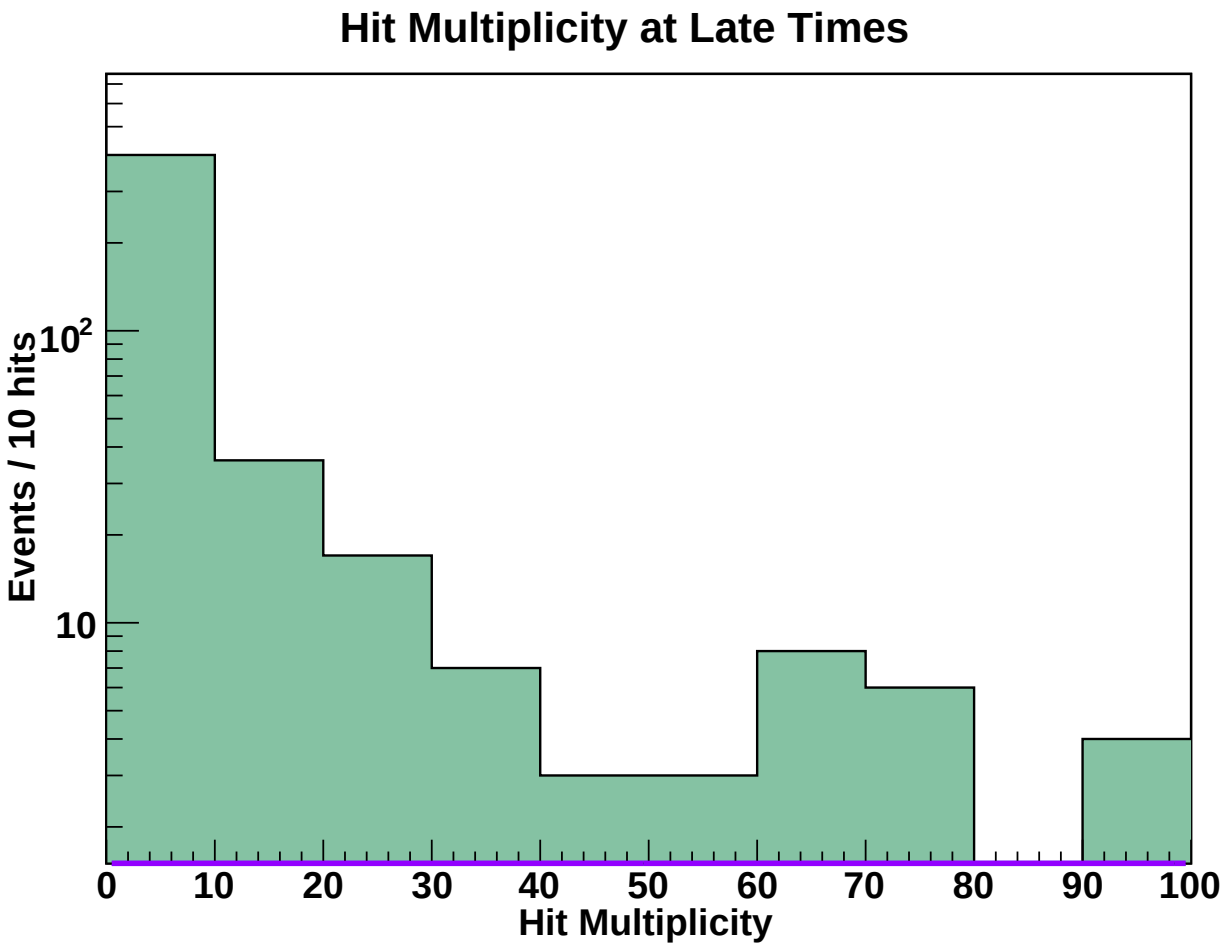
A quick way to see this is in the hit multiplicity (the number of photon hits) in the AD.


Hit Multiplicity at Early Times
Events / 10 hits
10^2
10
1
0
200
400
600
800
1000
1200
Hit Multiplicity


Hit Multiplicity at Late Times
Events / 10 hits
10^2
10
1
0
200
400
600
800
1000
1200
Hit Multiplicity



Gd: $131 \pm 9 \frac{photons}{MeV}$ H/C: 149 ± 26 Then one one expect an epithermal neutron to have a few tens of photons in the AD.


Hit Multiplicity at Late Times
Events / 10 hits
10^2
10
0
10
20
30
40
50
60
70
80
90
100
Hit Multiplicity

I'll make this more quantitative next week with some calculations of neutron transport to compare to the simulation.